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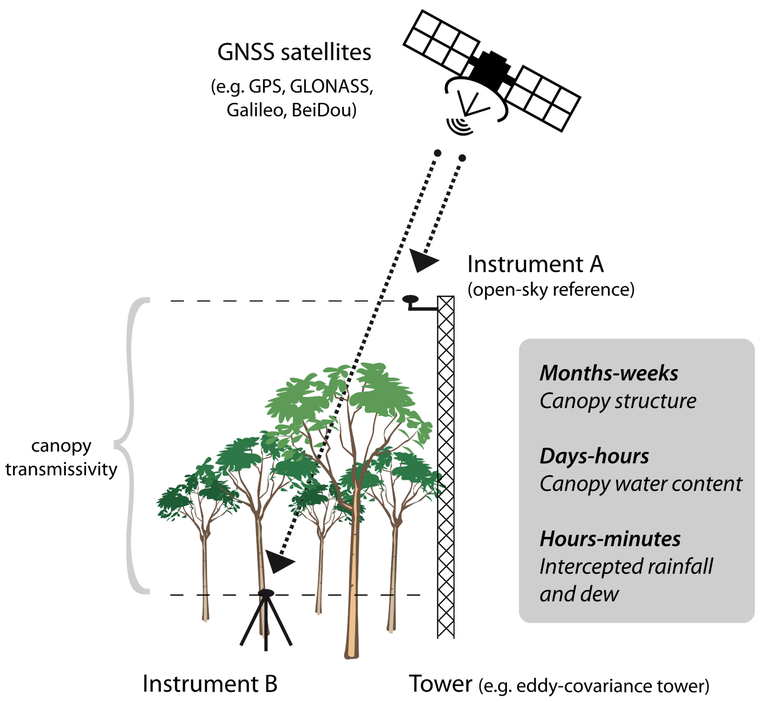
# VODnet: a virtual GNSS-T VOD network for monitoring of forest water budget and structure


Benjamin Brede[1], Konstantin Schellenberg[2,3,4], Adriano Camps[5,6,7], David Chaparro[5], Alexander Damm[9], Matthias Forkel[10], Christian Frankenberg[11], Abesh Ghosh[12], Henrik Hartmann[13,14,3], Martin Herold[1], Vincent Humphrey[15], Thomas Jagdhuber[4,16], Alexandra Konings[17], Mehmet Kurum[12], Michael Niederberger[9], Christiane Schmullius[2], Timothée Stassin[1], Susan Steele-Dunne[18], Nathan van der Borght[18], Martin Strube[3], Paul Vermunt[19], Yitong Yao[11], Albert Monteith[20], Elliot Richards[21], Henrik Persson[22], Benjamin Lecart[23], François Jonard[23]

[1]GFZ Helmholtz Centre for Geosciences, [2]Friedrich Schiller University Jena, [3]Max Planck Institute for Biogeochemistry, [4]German Aerospace Center (DLR), [5]Universitat Politècnica de Catalunya, [6]IEEC/UPC, [7]ASPIRE Visiting International Professor UAEU, [8]Centre for Ecological Research and Forestry Applications (CREAF), [9]University of Zurich, [10]TU Dresden, [11]California Institute of Technology, [12]University of Georgia, [13]Federal Research Institute for Cultivated Plants, [14]Georg-August-University Goettingen, [15]Meteoswiss, [16]University of Augsburg, [17]Stanford University, [18]TU Delft, [19]University of Twente, [20]Chalmers University of Technology, [21]Smithsonian Institution, [22]Sveriges Lantbruksuniversitet SLU, [23]University of Liège

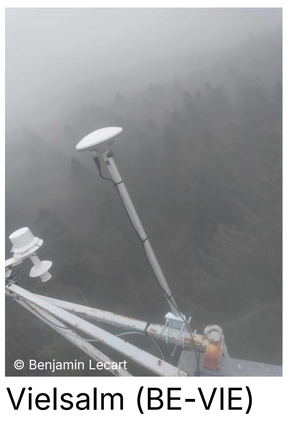

## Motivation: What is GNSS-T VOD?

EM wave interaction with vegetation canopies remains a fundamental research question of biosphere remote sensing. This is relevant to interpret satellite observations and understand large-scale biosphere processes. The remote sensing community is still waiting for a well representative calibration and validation network for this interaction.




(Humphrey & Frankenberg 2023)

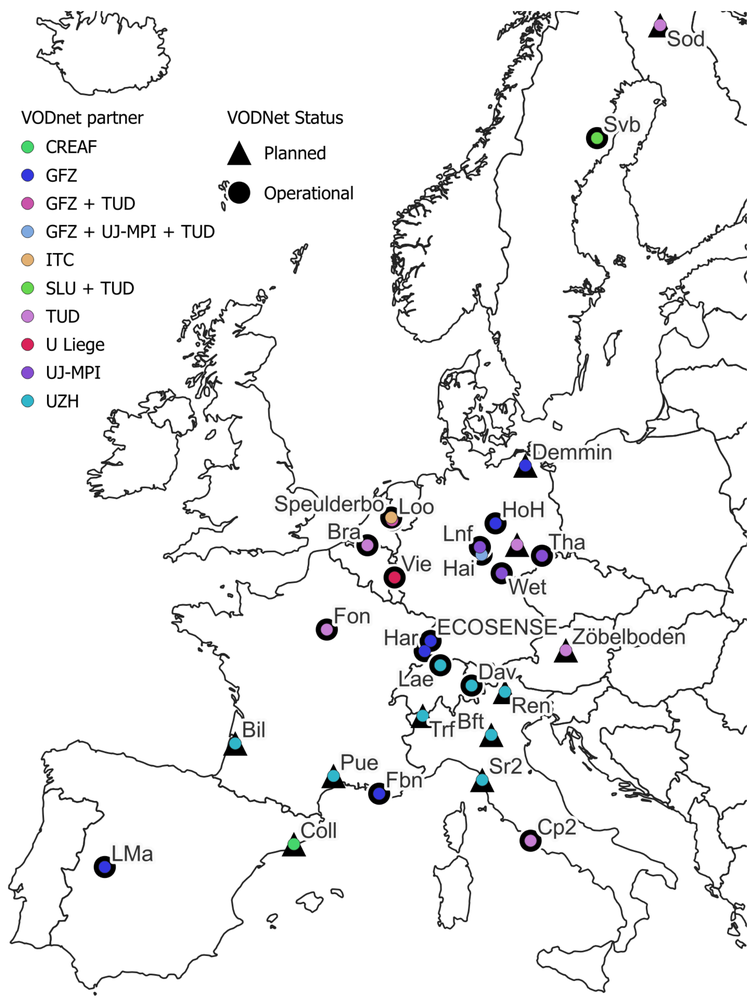
VODnet is a potential answer. VODnet is a collection of in situ sites that operate ground-based GNSS Transmissometry (GNSS-T) set ups to measure in hyper-temporal resolution the vegetation optical depth (VOD). VOD is a wave-medium interaction parameter and **contains information on the biomass, water (internal & external) and structure of canopies**. It is also directly retrievable from radiative transfer model (RTM)-based analyses of active or passive microwave remote sensing data. Hence, for the first time VODnet enables the **direct comparison of VOD** from in situ sites across a diversity of biomes with collocated remote sensing data. This will foster algorithm development for estimation of biomass (dry & wet), water content / potential, interception & dew as well as structure and shape of canopies. This means VODnet creates **real-world field laboratories** on assessing the canopy information (states & dynamics) contained in VOD.




Vielsalm (BE-VIE)

Davos

## The Network




Additonal:

- US-MOz (Missouri, CalTech) | operational
- Whitehall forest (Georgia, U Georgia) | operational
- Huntington Gardens (California, CalTech) | abandoned
- Paracou (French Guiana, GFZ) | operational
- Yangambi (DRC, GFZ) | planned

## Instrumentation

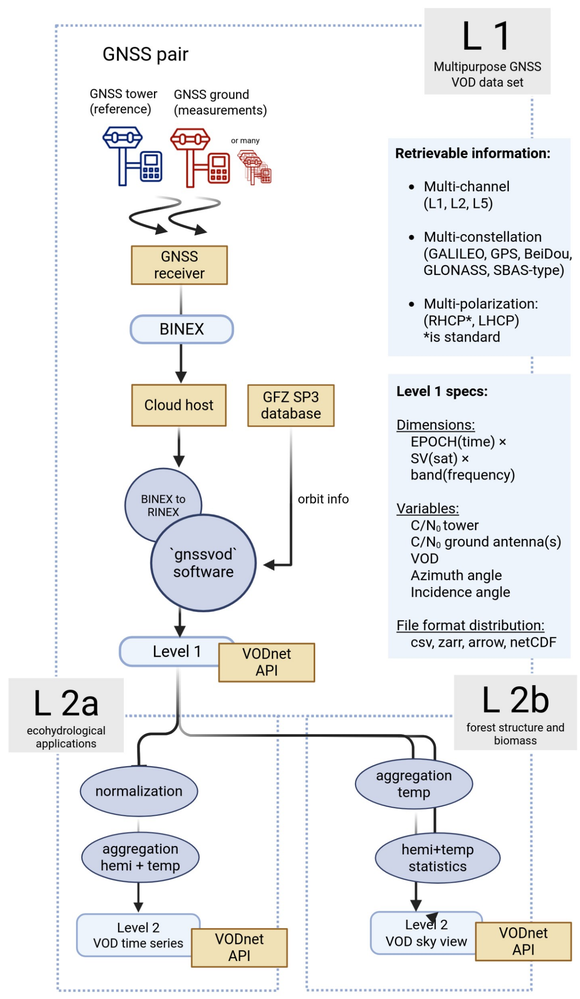
Across the network, a range of multi-frequency (L1/L2/L5), multi-constellation (GPS, GLONASS, Galileo, Beidou) GNSS receiver chips are in use. They range from low-cost (ublox ZED-F9P) to survey-grade (Septentrio mosaic-X5). Typically, survey-grade antennas are used. Most sites are connected to internet and direct data upload, allowing low latency and possibly near-real time application.

GNSS below canopy at Paracou

Uni Georgia mobile GNSS-T at US-MOz

Reference antenna at Svartberget

## Processing




Based on the GNSSVOD python toolkit (Humphrey 2025), a common data pipeline for the various partners' setups will be developed, incl. readers accounting for divers receiver hardware.

## Objectives of network partners

- Quantify uncertainties inherent in GNSS-T observations
- Understand diurnal variation in leaf & stem water status, water potential, plus estimation of live fuel moisture content
- Characterise forest structure, e.g. canopy gap fraction, in dependence of forest type
- Understand interaction of microwaves with vegetation
- Calibration/Validation of satellite-based VOD to improve global soil moisture, water status and biomass retrievals

## Synthesis

GNSS-T VOD has caught the attention of a diverse range of research institutes who are investing in infrastructure and exploration of the signal. A combined exploitation of sites covers large parts of western Europe.

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